B-Mode Sonographic Assessment of the Posterior Circumflex Humeral Artery

The SPI-US Protocol—A Technical Procedure in 4 Steps

Daan van de Pol, MD, PhD, Mario Maas, MD, PhD, Aart Terpstra, RVT, Marja Pannekoek-Hekman, RVT, P. Paul F. M. Kuijer, PhD, R. Nils Planken, MD, PhD

Elite overhead athletes are at risk of vascular injury due to repetitive abduction and external rotation of the dominant arm. The posterior circumflex humeral artery (PCHA) is prone to degeneration, aneurysm formation, and thrombosis in elite volleyball players and baseball pitchers. The prevalence of PCHA-related thromboembolic complications is unknown in this population. However, the prevalence of symptoms associated with digital ischemia is 31% in elite volleyball players. A standardized noninvasive imaging tool will aid in early detection of PCHA injury, prevention of thromboembolic complications, and measurement reproducibility. A standardized vascular sonographic protocol for assessment of the proximal PCHA (SPI-US protocol [Shoulder PCHA Pathology and Digital Ischemia–Ultrasound protocol]) is presented.

Key Words—aneurysm; embolization; humeral artery; posterior circumflex humeral artery; sonography; vascular ultrasound; volleyball

Elite volleyball players frequently have cold, discolored, and painful fingers in the dominant hand, which might be the result of emboli derived from the posterior circumflex humeral artery (PCHA) in the ipsilateral shoulder.[1] The PCHA is a side branch of the third part of the axillary artery (AA) and is prone to degeneration in elite overhead athletes, such as volleyball players and baseball pitchers, as a result of vascular injury due to repetitive abduction and external rotation of the arm.[1–14] This repetitive arterial injury can lead to degeneration, aneurysm formation, thrombosis, and distal embolization. The prevalence of elite overhead athletes with PCHA-related thromboembolic complications is still unknown. However, the prevalence of digital ischemic symptoms is as high as 31% in elite volleyball players.[1] A late diagnosis can disable the overhead athlete and threaten the athlete's career.[15]

Correct and timely recognition of signs and symptoms of embolization is key in diagnosis. An imaging modality of interest is vascular sonography, which is readily available, applicable on-site, inexpensive, and patient friendly. In general, sonography is the first-line imaging modality for aneurysm assessment. It enables noninvasive and patient-friendly measurement of vessel diameters and detection of intravascular thrombi.[16] Early detection of PCHA degeneration, aneurysm formation, and intravascular thrombosis can potentially prevent thromboembolic complications and irreversible tissue damage. Currently, there is no standardized vascu-

Received May 14, 2015, from the Department of Radiology (D.v.d.P., M.M., A.T., M.P.-H., R.N.P.) and Coronel Institute of Occupational Health, Academic Medical Center/University of Amsterdam, Amsterdam, the Netherlands (P.P.F.M.K.). Revision requested July 7, 2015. Revised manuscript accepted for publication August 25, 2015.

Address correspondence to Daan van de Pol, MD, PhD, Department of Radiology, Academic Medical Center/University of Amsterdam, PO Box 22700, NL-1100 DE Amsterdam, the Netherlands.

E-mail: daanvandepol@gmail.com

Abbreviations

AA, axillary artery; DBA, deep brachial artery; PCHA, posterior circumflex humeral artery

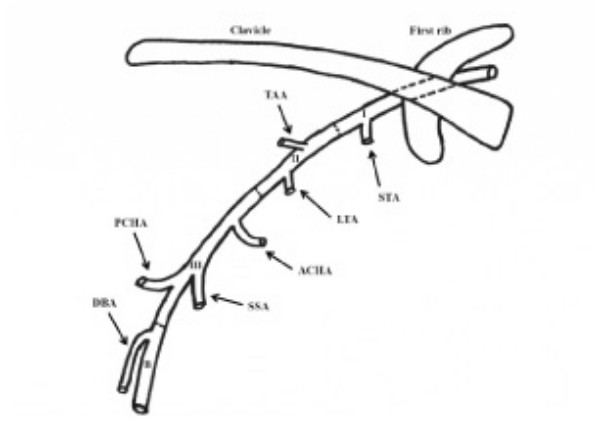
doi:10.7863/ultra.15.05037

lar sonographic protocol for the PCHA.[15] A standardized sonographic protocol is important because worldwide standardization and implementation will aid in targeted and accurate PCHA imaging.

The PCHA is a relatively small branch arising from the AA. The AA is a continuation of the subclavian artery distal to the first rib and gives rise to 6 branches, according to most descriptions.[17,18] The superior thoracic artery arises from the first part of the AA. The thoracoacromial artery and lateral thoracic artery arise from the second part. Three branches arise from the third part: the subscapular artery, anterior circumflex humeral artery, and the PCHA (Figure 1).[17,18] The PCHA frequently is the last branch arising from the AA. However, the deep brachial artery (DBA) arising from the proximal brachial artery frequently has an aberrant origin, may arise from the dorsal AA nearby, and may closely resemble the PCHA.[19–21] The PCHA is prone to degeneration in overhead athletes, whereas the DBA has not been reported to be at risk in overhead athletes in the medical literature. Therefore, it is important to discriminate the PCHA from the DBA. The prevalence of PCHA origin variations is as high as 33% to 42%. Common PCHA anatomic variants include a common trunk of the subscapular artery and PCHA (12%–34%; Figure 2) and a common trunk of the PCHA and DBA (8%; Figure 3).[17,18]

The proximal PCHA is characterized by its dorsal origin, slight obtuse angle, and curved course running along the dorsal surgical neck of the humeral bone, deflecting from the AA. The proximal DBA is also characterized by a dorsal origin but had a sharp angle and a straight course running almost parallel to the AA toward the triceps brachii muscle. This anatomic knowledge is important for correct PCHA identification.

Figure 1. Classic PCHA origin from the AA. I indicates first part of the AA; II, second part of the AA; III, third part of the AA; ACHA, anterior circumflex humeral artery; B, brachial artery; LTA, lateral thoracic artery; SSA, subscapular artery; STA, superior thoracic artery; and TAA, thoracoacromial artery.



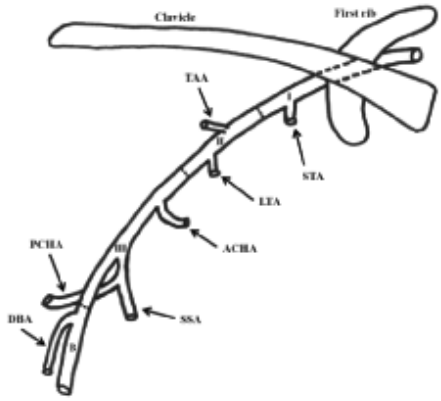
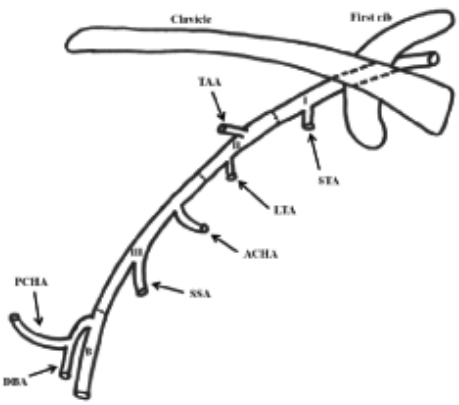


Figure 2. Common trunk of the PCHA and subscapular artery. Abbreviations are as in Figure 1.

An aneurysm can be defined as a segmental vessel dilatation of greater than 50% compared to the closest normal-appearing vessel segment proximal or distal to the aneurysmatic segment.[22] An example of an aneurysmatic PCHA in an elite volleyball player is shown in Figure 4.

A known limitation of sonography is that it is observer dependent, which may limit its diagnostic accuracy. Both cross-sectional and longitudinal views are important for identifying vessels and their course and localizing abnormalities. Furthermore, the reproducibility of vascular diameter measurements can be improved by using both cross-sectional and longitudinal views for assessment of vascular diameters. The cross-sectional diameter measurement should be performed perpendicular to the center

Figure 3. Common trunk of the PCHA and DBA. Abbreviations are as in Figure 1.



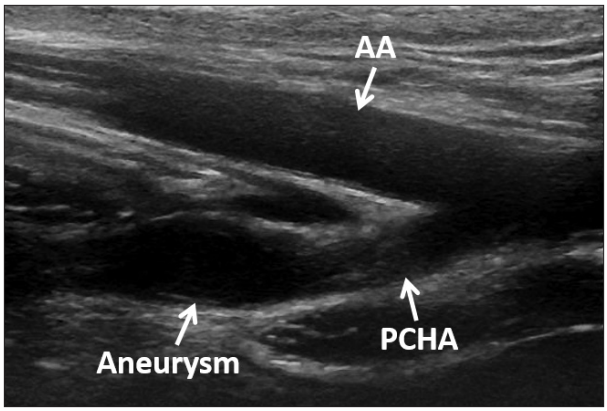


Figure 4. Longitudinal B-mode sonogram of an aneurysmatic proximal PCHA in a professional volleyball player.

line of the vessel, whereas in the longitudinal view, the diameter measurement should be performed along the center line. Standardization of vascular sonographic protocols is important for improving interobserver and intraobserver reproducibility.[23,24] However, a standardized PCHA sonographic protocol is currently not available to enable accurate diagnosis of PCHA injury. Therefore, we present a 4-step standardized vascular sonographic protocol for assessment of the proximal PCHA: the SPI-US protocol (Shoulder PCHA Pathology and Digital Ischemia–Ultrasound protocol).

Figure 5. Participant's position during the examination.

Sonographic Protocol

Step 1

The patient is seated next to the operator with the target arm in 60° abduction and the hand resting on the iliac crest (Figure 5). A high-frequency broadband linear array transducer is positioned at a sagittal oblique orientation in the axillary pit, directed toward the glenohumeral joint. The AA and axillary vein are identified by a cross-sectional sweep and longitudinal view. Both views are important for identifying the course and caliber of the vessels and localizing abnormalities. In general, the axillary vein is larger than the AA and is compressible, whereas the AA is not. An important landmark is the large-caliber thoracoacromial artery arising from the dorsal side of the AA (Figure 6).

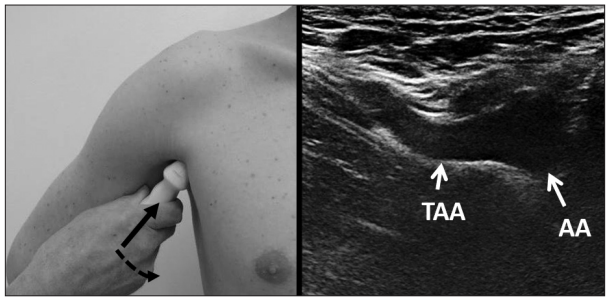
Step 2

A cross-sectional sweep is performed from the axillary pit down to the origin of the brachial artery for a general anatomic evaluation, localization of side branches, and specific assessment of the PCHA and DBA.

Step 3

The PCHA and DBA are identified. The PCHA origin is located proximal to the DBA origin. The proximal PCHA is characterized by its dorsal origin and curved course running along the dorsal surgical neck of the humeral bone, deflecting from the AA (Figures 7 and 8). The proximal DBA is also characterized by a dorsal origin and has a straight course running almost parallel to the AA toward the triceps brachii muscle. The DBA is the last dorsal branch of the AA in the axillary pit (Figure 9).

Figure 6. Cross-sectional view at the proximal axillary pit. TAA indicates thoracoacromial artery.



Step 4

The PCHA and DBA diameters are measured at an approximately 1-cm distance from the origin. In the event of PCHA dilatation, the maximum diameter of the PCHA is measured. In addition, the diameter of the closest normal-appearing PCHA vessel segment proximal, or otherwise distal, to the dilated vessel segment is measured. Additionally, the presence of intravascular thrombosis or vessel occlusion is identified and recorded. Waveform characteristics are obtained to visualize a triphasic or blunted signal. A blunted signal is correlated with more-distal occlusion.

Discussion

Volleyball is among the most widely played sports in the world and is played by around 260 million people regularly. Elite volleyball players worldwide are potentially at risk of PCHA aneurysms and thrombosis with distal embolization.[1] The diagnosis is established on the basis of history taking, physical examination, and diagnostic imaging, both noninvasive and invasive. Noninvasive tests, such as digital photoplethysmography and vascular sonography, are used in the workup toward invasive testing: ie, digital subtraction angiography, which is the reference standard, or less-invasive computed tomographic angiography. Both are associated with ionizing radiation and the use of contrast media. However, these modalities are currently required for diagnosis and treatment planning. Athletes present themselves late in disease with symptoms of digital ischemia in daily life. Symptoms include coldness, discoloration, pain, and paresthesia. These symptoms may cause severe discomfort and a reduced daily quality of life and may ultimately lead to necrosis and finger loss when trivialized.

In an early stage of disease, the aneurysm is occult as long as the player is free of symptoms. Symptoms might only manifest after overhead movements in volleyball,

Figure 7. Cross-sectional view of the PCHA. 1, At the PCHA origin. 2, Halfway to the surgical neck of the humerus. 3, Along the surgical neck of the humerus. HH indicates humeral head.

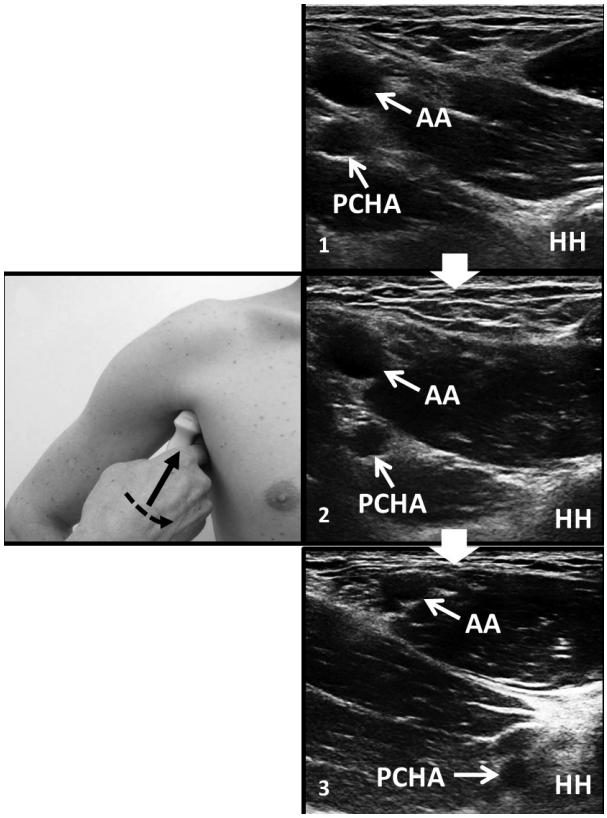


Figure 8. Longitudinal view of the PCHA.

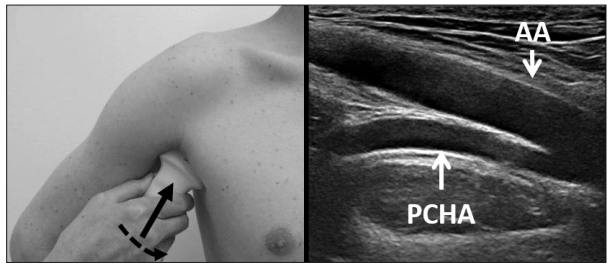
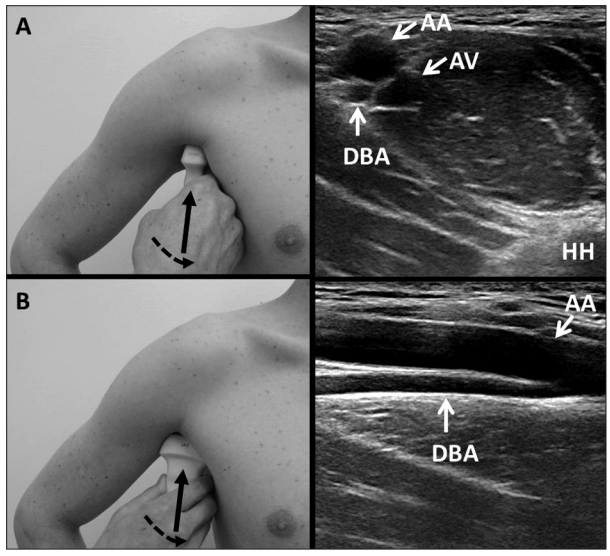


Figure 9. **A**, Cross-sectional view of the DBA. **B**, Longitudinal view of the DBA. AV indicates axillary vein; and HH, humeral head.



when emboli are squeezed out of the aneurysmatic and thrombosed PCHA into the AA and embolize into the digital circulation. This condition can lead to transient local coldness and discoloration during or directly after volleyball.[1] A screening questionnaire can be used to triage athletes who have vague symptoms during volleyball, which are possibly related to distal embolization.[1] These athletes might benefit from noninvasive screening diagnostic imaging in an early stage to objectify local PCHA injury. A convenient imaging modality is vascular sonography, which is readily available, inexpensive, and patient friendly and enables on-site application.

Vascular sonography has been reported previously to visualize and measure blood flow in the distal PCHA in healthy volunteers by a posterolateral approach on the upper arm.[25] However, most PCHA injuries in volleyball players have been reported in the proximal part of the PCHA, near the takeoff from the AA.[3,14,15] These findings are consistent with the location of injuries seen in volleyball players who were evaluated and treated in our academic hospital.[1,2,5,6]

The standardized vascular (SPI-US) protocol presented here is quick and easy and enables on-site application, which can aid in early detection of PCHA injury. Furthermore, this protocol can be used in a clinical setting in the workup toward diagnosis and treatment planning. Standardization of sonographic PCHA imaging will contribute to the reproducibility of the acquired measurements, intercollegial exchange of reference values, and more knowledge on this overhead-sport–specific injury. The protocol instructions and corresponding images provide clear guidance for identification and assessment of the PCHA. International dissemination of this protocol should make it possible to identify PCHA injury at an early stage. A first step to do so was taken during a large international beach volleyball tournament in the summer of 2014.

In conclusion, we have presented a standardized 5- to 10-minute vascular sonographic (SPI-US) protocol for PCHA assessment to detect aneurysm-related embolization. The results of a subsequent study to determine the reproducibility and accuracy of the protocol are expected.

References

1. van de Pol D, Kuijer PPFM, Langenhorst T, Maas M. High prevalence of self-reported symptoms of digital ischemia in elite male volleyball players in the netherlands: a cross-sectional national survey. *Am J Sports Med* 2012; 40:2296–2302.
2. Atema JJ, Ünlü Ç, Reekers JA, Idu MM. Posterior circumflex humeral artery injury with distal embolisation in professional volleyball players: a discussion of three cases. *Eur J Vasc Endovasc Surg* 2012; 44:195–198.
3. Vlychou M, Spanomichos G, Chatziioannou A, Georganas M, Zavras GM. Embolisation of a traumatic aneurysm of the posterior circumflex humeral artery in a volleyball player. *Br J Sports Med* 2001; 35:136–137.
4. McIntosh A, Hassan I, Cherry K, Dahm D. Posterior circumflex humeral artery aneurysm in 2 professional volleyball players. *Am J Orthop* (*Belle Mead NJ*) 2006; 35:33–36.
5. Reekers JA, Koedam N. Re: volleyball-related ischemia of the hand. *Cardiovasc Intervent Radiol* 1998; 21:261.
6. Reekers JA, den Hartog BM, Kuyper CF, Kromhout JG, Peeters FL. Traumatic aneurysm of the posterior circumflex humeral artery: a volleyball player's disease? *J Vasc Interv Radiol* 1993; 4:405–408.
7. McCarthy WJ, Yao JST, Schafer MF, et al. Upper extremity arterial injury in athletes. *J Vasc Surg* 1989; 9:317–327.
8. Nuber GW, McCarthy WJ, Yao JST, Schafer MF, Suker JR. Arterial abnormalities of the shoulder in athletes. *Am J Sports Med* 1990; 18:514–519.
9. Durham JR, Yao JST, Pearce WH, Nuber GM, McCarthy WJ. Arterial injuries in the thoracic outlet syndrome. *J Vasc Surg* 1995; 21:57–70.
10. Kee ST, Dake MD, Wolfe-Johnson B, Semba CP, Zarins CK, Olcott C IV. Ischemia of the throwing hand in major league baseball pitchers: embolic occlusion from aneurysms of axillary artery branches. *J Vasc Interv Radiol* 1995; 6:979–982.
11. Todd GJ, Benvenisty AI, Hershon S, Bigliani LU. Aneurysms of the mid axillary artery in major league baseball pitchers: a report of two cases. *J Vasc Surg* 1998; 28:702–707.
12. Schneider K, Kasparyan NG, Altchek DW, Fantini GA, Weiland AJ. An aneurysm involving the axillary artery and its branch vessels in a major league baseball pitcher: a case report and review of the literature. *Am J Sports Med* 1999; 27:370–375.
13. Arko FR, Harris EJ, Zarins CK, Olcott C. Vascular complications in high-performance athletes. *J Vasc Surg* 2001; 33:935–942.
14. Stänz K, Wedler V, Köpfli P, Künzi W, Pfammatter T. Compression syndrome of the arteria circumflexa humeri posterior in a volleyball player [in German]. *Vasa* 2001; 30:229–232.
15. Brown SAN, Doolittle DA, Bohanon CJ, et al. Quadrilateral space syndrome. *Mayo Clin Proc* 2015; 90:382–394.
16. Hall HA, Minc S, Babrowski T. Peripheral artery aneurysm. *Surg Clin North Am* 2013; 93:911–923, ix.
17. Hattori Y, Doi K, Sakamoto S, Satbhai N. Anatomic variations in branching patterns of the axillary artery: a multidetector-row computed tomography angiography study. *J Reconstr Microsurg* 2013; 29:531–536.
18. Olinger A, Benninger B. Branching patterns of the lateral thoracic, subscapular, and posterior circumflex humeral arteries and their relationship to the posterior cord of the brachial plexus. *Clin Anat* 2010; 23:407–412.
19. Bagoji IB, Hadimani GA, Bannur BM, Patil BG, Bharatha A. A unique branching pattern of the axillary artery: a case report. *J Clin Diagn Res* 2013; 7:2939–2940.

20. Cavdar S, Zeybek A, Bayramicli M. Rare variation of the axillary artery. *Clin Anat* 2000; 13:66–68.
21. Naveen K, Jyothsna P, Nayak SB, et al. Variant origin of an arterial trunk from axillary artery continuing as profunda brachii artery: a unique arterial variation in the axilla and its clinical implications. *Ethiop J Health Sci* 2014; 24:93–96.
22. Johnston KW, Rutherford RB, Tilson MD, Shah DM, Hollier L, Stanley JC. Suggested standards for reporting on arterial aneurysms. *J Vasc Surg* 1991; 13:452–458.
23. Planken RN, Keuter XHA, Hoeks APG, et al. Diameter measurements of the forearm cephalic vein prior to vascular access creation in end-stage renal disease patients: graduated pressure cuff versus tourniquet vessel dilatation. *Nephrol Dial Transplant* 2006; 21:802–806.
24. Planken RN, Keuter XH, Kessels AG, Hoeks AP, Leiner T, Tordoir JH. Forearm cephalic vein cross-sectional area changes at incremental congestion pressures: towards a standardized and reproducible vein mapping protocol. *J Vasc Surg* 2006; 44:353–358.
25. Robinson D, Marks P, Schneider-Kolsky M. Ultrasound of the posterior circumflex humeral artery: posterior circumflex humeral artery. *J Med Imaging Radiat Oncol* 2010; 54:219–223.